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NORTH AMERICAN AVIATION, INC.

COLUMBUS DIVISION COLUMBUS 16, OHIO

ENGINEERING DEPARTMENT

DOD HIGH STRENGTH TITANIUM
ALLOY SHEET RESEARCH PROGRAM

1 August 1962

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ABSTRACT

This report contains data obtained from evaluations conducted on the 5Al-5Sn-5Zr and 7Al-12Zr alloys to determine the precautions necessary to prevent stress corrosion cracking problems during forming.

Normal precautions during manufacturing to prevent contamination of the 5Al-2½Sn titanium alloy details are adequate for the super alpha titanium alloys. A range of 1300F for two and one half hours to 1500F for one half hour produces 88 to 100% stress relief of both alloys.

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1. INTRODUCTION: North American Aviation, Inc., Columbus Division is evaluating the quality, uniformity, creep properties, thermal stability and fabrication characteristics of the 5Al-5Sn-5Zr and 7Al-12Zr super alpha titanium sheet alloys under the Department of Defense Titanium Sheet Rolling Program. This, the Eighteenth Progress Report under BuWeps Contract NOas 57-785d contains fabrication stress corrosion and contamination data obtained during the period of 31 May 1962 to 31 August 1962.

2. OBJECTIVES: The objectives of this program are to obtain design criteria and to determine fabrication characteristics of the materials being tested.

3. SCOPE: The program includes receiving inspection of materials, determination of mechanical properties at room and elevated temperatures, creep properties (welded and unwelded), thermal stability, formability, fabrication stress and contamination studies, machinability, dimpling, fusion and resistance welding tests.

4. SUMMARY: Data obtained from tests conducted to determine the stress and contamination levels which would produce stress corrosion cracking during forming and the precautions necessary revealed;

The alloys are susceptible to stress corrosion cracking when contaminated with chlorides.

Stress corrosion cracking can be prevented by cleaning with uninhibited heavy duty alkaline cleaner prior to elevated temperature forming and the use of interstage stress relief operations.

Stress relief of both alloys can be accomplished as low as 1300F for times to 2½ hours and optimum stress relief is obtained at 1500F for ½ hour.

Recommended forming sequences to avoid stress corrosion and contamination problems are to prepare blanks, clean, form, clean, hot size, stress relieve, and pickle.

5. TEST PROGRAM: The 5Al-5Sn-5Zr and 7Al-12Zr alloy sheet were evaluated to determine;

If the alloys were susceptible to stress corrosion cracking when contaminated with materials known to cause cracking in the 5Al-2.5Sn alloy.

The handling procedures necessary to prevent contamination.

The stress relief necessary to prevent cracking.

5.1 Material Tested: Both the stress corrosion and stress relief tests were conducted on laboratory samples and specimens formed in production departments taken from .040 gage sheet from two heats of each of the two alloys.

Supplier	Alloy	Heat #	Sheet #	NAA #
TMCA	7-12	V1787M	A7325-5	63
RMI	7-12	32558	3175-7	65
TMCA	5-5-5	V1813M	A7129-5	76
TMCA	5-5-5	V1785M	A7558-8	77

5.2 Test Samples: Strap type, .040 X 3/4 X 8" lg, longitudinal samples were used for laboratory stress corrosion & stress relief testing. (The longitudinal direction was selected because yield strengths are normally lower in this direction). Test samples were prepared by shearing, burring and then cleaned with methyl ethyl ketone. All samples were given the white glove treatment during handling. Thermal processing of the two groups of samples was accomplished in an electric, stagnant air, furnace.

5.3 Stress Corrosion Samples - Testing: Stress corrosion tests were conducted by contaminating the laboratory samples from two heats of both alloys with a paste composed of 20 percent sodium chloride solution and infusorial earths. (Residual inactive elements). The samples were preloaded from 12 ksi to 108 ksi and exposed at 1200F for one hour in the furnace. Examination of each sample was done at room temperature using a 50X magnification and dye penetrant to determine if cracking had occurred.

5.3.1 Results - The results obtained from the stress corrosion samples (Reference Figures 1 & 2 and Table I) are summarized below:

Complete fracture developed in all samples of both alloys when preloaded to 72 ksi or higher.

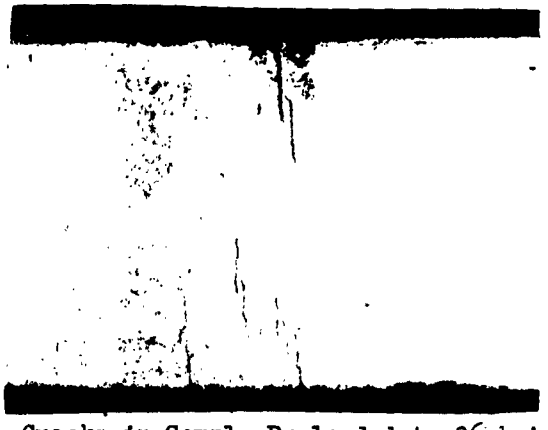
Visual cracks developed in all samples of both alloys which were preloaded from 48 ksi to 60 ksi.

Macroscopic cracks (5X) developed in all samples preloaded at 36 ksi.

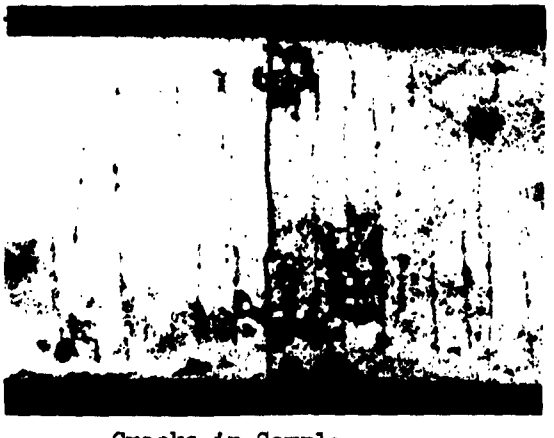
No cracks were detected in any sample of either alloy when the preload was less than 36 ksi.

FIGURE 1

Typical Examples of Stress Corrosion Cracking



Cracks in Sample Preloaded to 36 ksi
5Al-5Sn-5Zr Alloy (5X)

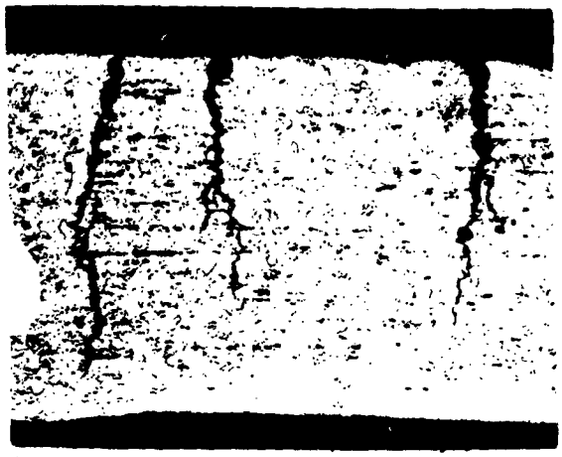


Cracks in Sample
Preloaded to 72 ksi
7Al-12Zr Alloy
(5X)

Failure of Sample
Preloaded to 108 ksi
7Al-12Zr Alloy
(5X)

FIGURE 2.

Photomicrographs of Typical Examples of Stress Corrosion Cracking



Stress Corrosion Cracks in 5Al-5Zr-5Sn Alloy Preloaded to 72 ksi (50X)

Stress Corrosion Cracks in 7Al-12Zr Alloy Preloaded to 108 ksi (50X)

Stress Corrosion Cracks in 5Al-5Zr-5Sn Alloy Preloaded to 108 ksi (50X)

TABLE I

Results of Stress Corrosion Tests
Conducted on Both Alloys

Sample* Number	Preload (ksi)	Results
1	108	Complete failure
2	96	Complete failure
3	84	Complete failure
4	72	Complete failure
5	60	Visual cracks
6	40	Visual cracks
7	36	Macroscopic cracks
8	24	No cracks
9	12	No cracks

* Each sample represents three pieces of each alloy of each heat. The degree of cracking was most severe with the 7Al-12Zr alloy, however, the difference is not considered significant.

5.3.2 Discussion: A minimum stress level of 36 ksi was required to produce stress corrosion cracking under conditions of extreme contamination. The stress level required to cause cracking under lesser degrees of contamination is expected to be much higher and would not be encountered under normal manufacturing conditions. Special precautions such as white gloves will be necessary when the parts are subjected to higher stresses resulting from severe cold work in localized areas or in welding.

5.4 Stress Relief Samples - Testing:- Stress relief tests were conducted using the beam relaxation method described in AIME Transactions 1942 "Relief of Residual Stresses in Some Aluminum Alloys." This test involved preloading laboratory samples from two heats of each alloy to 95 percent of the yield strength and expose at 900, 1000, 1100, 1200, 1300, 1400 and 1500F for 30 to 210 minutes at 30 minute intervals. To determine the percent of relaxation the method described in the "Investigation of Stress Relief Procedures for Titanium Alloys" under WADC Report KB-955-M-2, Contract No AF33(616)2688 were used.

5.4.1 Results:- Test results indicate that a 88% stress relief can be obtained at 1300F for two and one half hours with the optimum 100% stress relief obtained at 1500F for one half hour for both alloys. Results of the beam relaxation tests are shown in Figures 3 & 4 and the maximum stress relief obtained at each temperature is listed in Tables II and III.

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FIGURE 3.

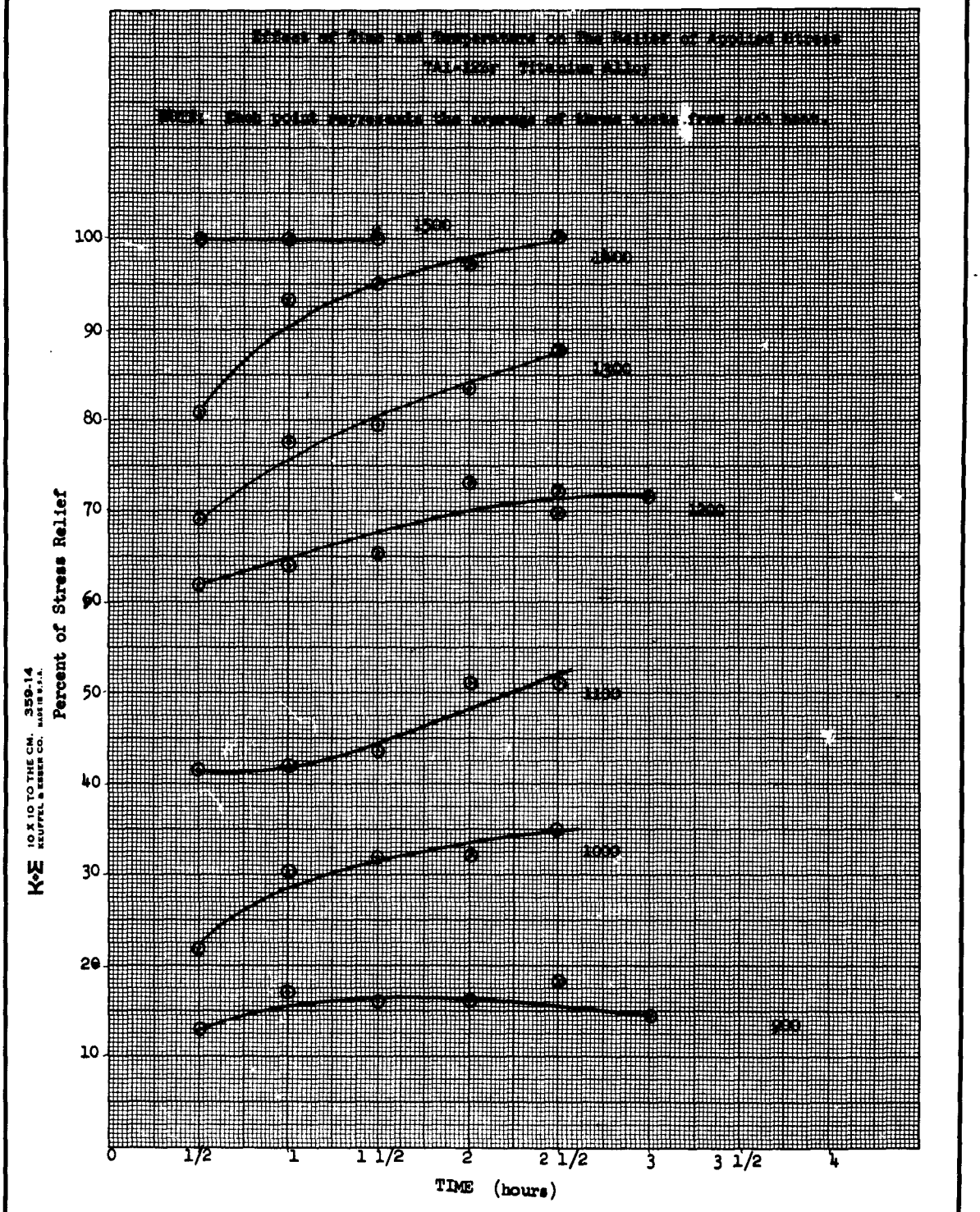

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FIGURE 4.

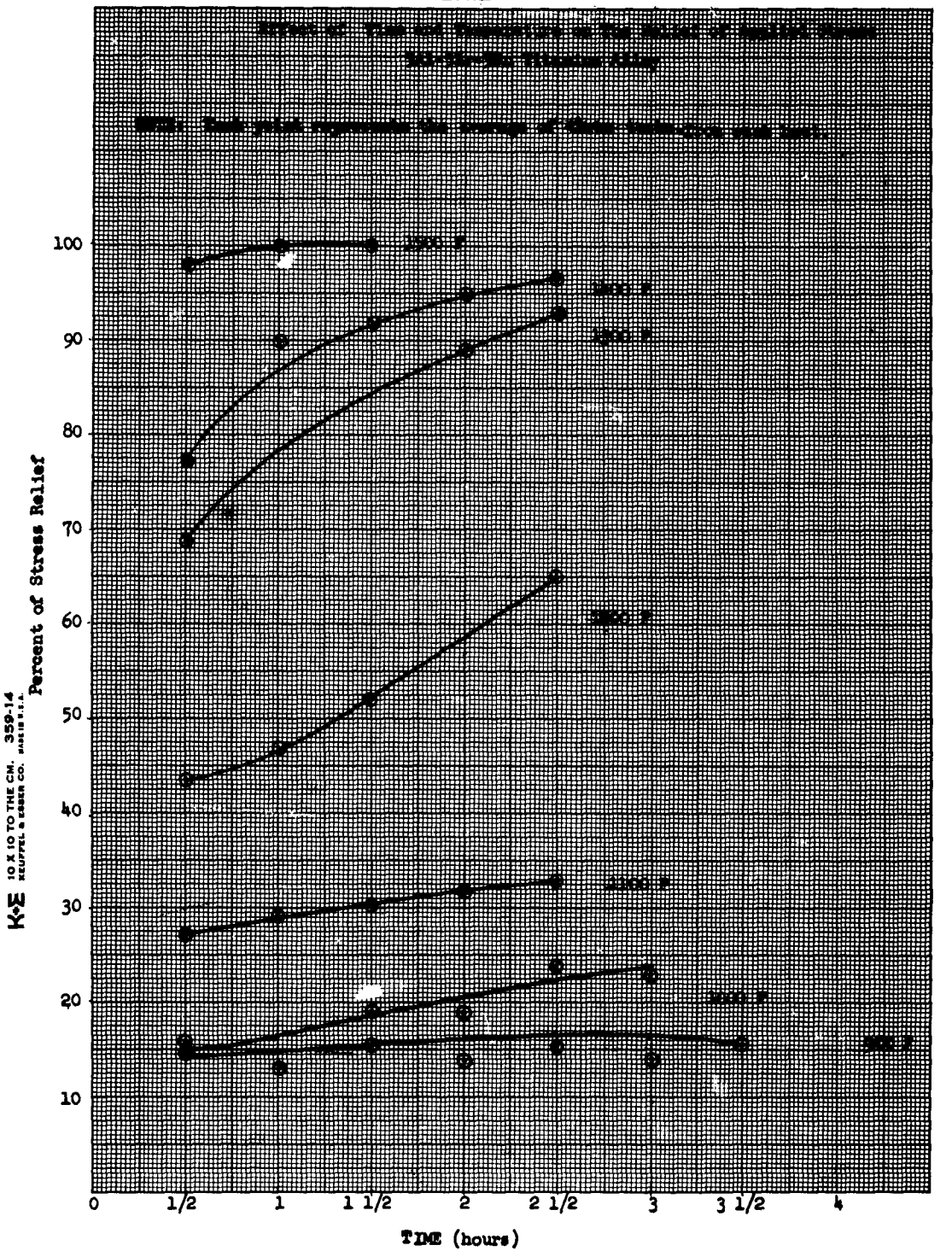

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TABLE II

MAXIMUM STRESS RELIEF OBTAINED ON 7Al-12Zr TITANIUM

Temperature (F)	Time (Hrs)	Percent Relief
900	3.5	15.0
1000	2.5	35.0
1100	2.5	50.0
1200	2.5	72.0
1300	2.5	87.0
1400	2.5	100.0
1500	0.5	100.0

TABLE III

MAXIMUM STRESS RELIEF OBTAINED ON 5Al-5Zr-5Sn TITANIUM

Temperature (F)	Time (Hrs)	Percent Relief
900	4.0	15.0
1000	3.0	22.0
1100	2.5	37.0
1200	2.5	65.0
1300	3.0	94.0
1400	2.5	97.0
1500	1.0	100.0

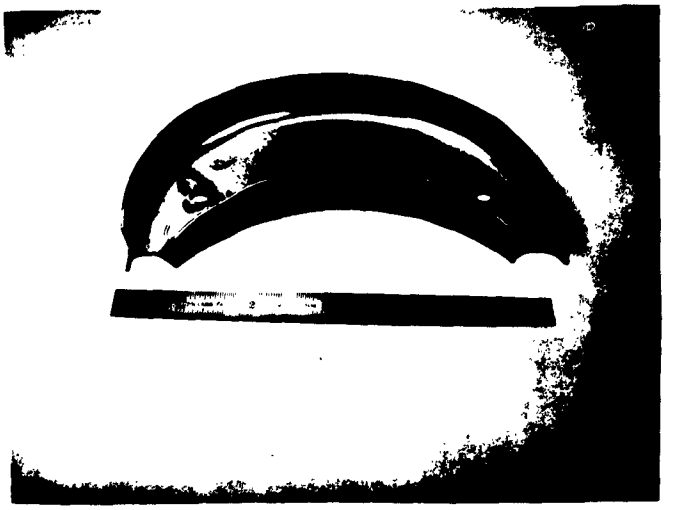
5.4.2 Discussion:- The data obtained indicates that the time required to obtain stress relief at a temperature lower than 1300F may be impractical for production purposes. Furthermore, it is questionable whether satisfactory stress relief can be obtained at a lower temperature. Depending on the production tooling and equipment available and/or necessary to obtain final dimensions during stress relief, the time and temperature required to obtain stress relief for both alloys appears adjustable within the indicated range.

5.5 Formed Specimens Testing:- In addition to the formability sequence specimens data, reported on Progress Report #17, eight (8) specimens were subjected to the processing indicated by the laboratory samples. The specimens were made by sawing, edges prepared, cleaned in an uninhibited heavy duty alkaline cleaner, formed at room temperature on a hydro press, cleaned, benched at elevated temperatures of 800 to 900 F for approximately 10 minutes each, cleaned, hot sized, stress relieved and pickled. One set of four (4), one specimen from each heat of each alloy were stress relieved at 1300 F for two and one half hours and a similar set stressed relieved at 1500 F for a half hour. As with the formability specimens, previously reported, no special precautions were taken with these specimens to prevent contact with chloride materials during this test.

5.5.1 Specimen Data: The configuration used for formed specimens was a hydro press specimen made from .040 gage sheet with a 15% stretch flange and a 12% shrink flange for both alloys. Specimens were longitudinal and identical in general configuration and preparation to the "formability specimens" previously reported. Figure 5, is a photograph of a typical formed specimen.

FIGURE 5

TYPICAL FORMABILITY SEQUENCE SPECIMEN



5.5.2 Results: - Macroscopic examination (50X) and dye penetrant inspection of the specimens revealed no cracks at any stage of the test sequences.

5.5.3 Discussion:- Based on the results of these formability processing sequence tests and the data obtained from the formability tests conducted earlier in the program it is recommended that production parts be cleaned prior to elevated temperature forming and that interstage stress relief operations be used as dicatated by the fabrication operations. The processing of formed specimens as presented in paragraph 5.5 is recommended for producing parts from these alloys. However, adjustments to accommodate cold worked welded or dimpled parts immediately preceding assembly may require special control of cleaning and

stress relief conditions in order to prevent stress corrosion cracking.

6. GENERAL: The stress corrosion and contamination data contained in this progress report complete these evaluations under this program.

7. FUTURE WORK: Creep properties determinations at 900 and 1100 F from 10 to 1000 hours are virtually complete and data will be reported in the Final Report.

REFERENCES

(Relative to the super alpha titanium sheet alloys evaluations)

Progress Report #14, Letter, 61CL4785, dated 24 July 1961, reporting no progress due to lack of material.

Progress Report #15, Letter, 61CL7332, dated 20 October 1961 reporting no progress due to delay in receiving material.

Progress Report #16, NA57H-527-16, dated 31 January 1962.

Progress Report #17, NA57H-527-17, dated 31 May 1962.

CONTRIBUTORS

NAA Columbus personnel responsible for specific evaluations and/or contributing data under this program are:

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